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<p>(21) International Application Number: PCT/CA99/00018</p> <p>(22) International Filing Date: 8 January 1999 (08.01.99)</p> <p>(30) Priority Data: 60/070,948 9 January 1998 (09.01.98) US</p> <p>(71) Applicant: THE GOVERNING COUNCIL OF THE UNIVERSITY OF TORONTO [CA/CA]; 106 Simcoe Hall, 27 King's College Circle, Toronto, Ontario M5S 1A1 (CA).</p> <p>(72) Inventors: ST. GEORGE-HYSLOP, Peter, H.; 210 Richview Avenue, Toronto, Ontario M5P 3G3 (CA). FRASER, Paul, E.; 611 Windermere Avenue, Toronto, Ontario M6S 3L9 (CA).</p> <p>(74) Agent: RAE, Patricia, A.; Sim & McBurney, 6th floor, 330 University Avenue, Toronto, Ontario M5G 1R7 (CA).</p>	<p>(81) Designed States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
<p>(54) Title: PRESENILIN PROTEIN INTERACTIONS</p> <p>(57) Abstract</p> <p>Disclosed is a method for identifying substances that alter the interaction of a presenilin protein with a presenilin-binding protein, including contacting at least the interacting domain of a presenilin protein to a presenilin-binding protein in the presence of a test substance, and measuring the interaction of the presenilin protein and the presenilin-binding protein. Also disclosed is a method for identifying substances that modulate the nuclear translocation of an armadillo protein, including providing a culture of cells that express the armadillo protein and a mutant presenilin protein, or a functional fragment thereof that binds an armadillo protein; contacting the culture with a test substance; inducing nuclear translocation of the armadillo protein in the cells; and measuring levels of nuclear armadillo protein as compared to a control as an indication of modulatory activity of the test substance. Further disclosed is a method for screening individuals for presenilin alleles associated with Alzheimer's Disease or related disorder, including obtaining cells from an individual to be tested for Alzheimer's Disease or a related disorder; inducing nuclear translocation of an armadillo protein in the cells, and measuring levels of the nuclear armadillo protein as compared to a control as an indication of the presence or absence of presenilin alleles associated with Alzheimer's Disease or a related disorder.</p>		

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PRESENILIN PROTEIN INTERACTIONS

FIELD OF THE INVENTION

The present invention relates generally to the field of neurological and physiological dysfunctions associated with Alzheimer's Disease. More particularly, the invention is concerned with the identification of proteins associated with Alzheimer's Disease, to methods of diagnosing Alzheimer's Disease and to methods of screening for candidate compounds which modulate the interaction of certain proteins, specifically *armadillo* repeat proteins, with presenilin proteins.

BACKGROUND OF THE INVENTION

Alzheimer's Disease (AD) is a degenerative disorder of the human central nervous system characterized by progressive memory impairment and cognitive and intellectual decline during mid to late adult life (*Katzman, 1986, N. Eng. J. Med.* 314:964-973). The disease is accompanied by a constellation of neuropathologic features principal amongst which are the presence of extracellular amyloid or senile plaques, and neurofibrillary tangles in neurons. The etiology of this disease is complex, although in some families it appears to be inherited as an autosomal dominant trait. Genetic studies have identified three genes associated with the development of AD, namely: (1) β -amyloid precursor protein (β APP) (*Chartier-Harlin et al., 1991, Nature* 353:844-846; *Goate et al., 1991, Nature* 349:704-706; *Murrell et al., 1991, Science* 254:97-99; *Karlinsky et al., 1992, Neurology* 42:1445-1453; *Mullan et al., 1992, Nature Genetics* 1:345-347); (2) presenilin-1 (PS1) (*Sherrington et al., 1995, Nature* 375:754-760); and (3) presenilin-2 (PS2) (*Rogaev et al., 1995, Nature* 376:775-778; *Levy-Lehad et al., 1995, Science* 269:970-973).

The presenilin genes (presenilin 1 - *PS1* and presenilin 2 - *PS2*) encode homologous polytopic transmembrane proteins that are expressed at low levels in intracellular membranes including the nuclear envelope, the endoplasmic reticulum, the Golgi apparatus and some as yet uncharacterised intracytoplasmic

vesicles in many different cell types including neuronal and non-neuronal cells (*Sherrington et al.*, 1995; *Rogaev et al.*, 1995; *Levy-Lahad et al.*, 1995; *Doan et al.*, 1996, *Neuron* 17:1023-1030; *Walter et al.*, 1996, *Molec. Medicine* 2:673-691; *De Strooper et al.*, 1997, *J. Biol. Chem* 272:3590-3598; *Lehmann et al.*, 1997, *J.Biol.Chem.* 272:12047-12051; *Li et al.*, 1997, *Cell* 90:917-927). Structural studies predict that the presenilins contain between six and eight transmembrane (TM) domains organized such that the N-terminus, the C-terminus, and a large hydrophilic loop following the sixth TM domain are located in the cytoplasm or nucleoplasm, while the hydrophilic loop between TM1 and TM2 is located within the lumen of membranous intracellular organelles (*Doan et al.*, 1996; *De Strooper et al.*, 1997; *Lehmann et al.*, 1997).

Missense mutations in the PS1 and PS2 genes are associated with the inherited forms of early-onset AD (*Sherrington et al.*, 1995, *Nature* 375:754-760; *Rogaev et al.*, 1995, *Nature* 376:775-778; *Levy-Lahad et al.*, 1995, *Science* 269: 970-973). Several lines of evidence have also suggested roles in developmental, apoptotic signalling and in the regulation of proteolytic cleavage of the b-amyloid precursor protein (bAPP) (*Levitan et al.*, 1995, *Nature* 377:351-354; *Wong et al.*, 1997, *Nature* 387:288-292; *Shen et al.*, 1997, *Cell* 89:629-639; *Wolozin et al.*, 1996, *Science* 274:1710-1713; *De Strooper et al.*, 1998, *Nature* 391:387-390). Nevertheless, it remains unclear just how these putative functions are mediated, or how they relate to the abnormal metabolism of the β APP associated with PS1 and PS2 mutations (*Martin et al.*, 1995, *NeuroReport* 7:217-220; *Scheuner et al.*, 1996, *Nature Med.* 2:864-870; *Citron et al.*, 1997, *Nature Med.* 3:67-72; *Duff et al.*, 1996, *Nature* 383:710-713; *Borchelt et al.*, 1996, *Neuron* 17:1005-1013).

The identification and cloning of normal as well as mutant PS1 and PS2 genes and gene products are described in detail in copending commonly assigned U.S. Application Serial Nos. 08/431,048, filed April 28, 1995; 08/496,841, filed June 28, 1995; 08/509,359, filed July 31, 1995; and 08/592,541, filed January 26, 1996, the disclosures of which are incorporated herein by reference.

There is speculation that onset of AD may be associated with aberrant interactions between mutant presenilin proteins and normal forms of PS-interacting proteins, and these changes may increase or decrease interactions present with normal PS1, or cause interaction with a mutation-specific PS-interacting protein. Such aberrant interactions also may result from normal presenilins binding to mutant forms of the PS-interacting proteins. Therefore, mutations in the PS-interacting proteins may also be causative of AD.

While the identification of normal and mutant forms of PS proteins has greatly facilitated development of diagnostics and therapeutics, a need exists for new methods and reagents to more accurately and effectively diagnose and treat AD.

SUMMARY OF THE INVENTION

Applicants have discovered that both PS1 and PS2 interact specifically with at least two members of the *armadillo* family of proteins (GT24/Neuronal Plakoglobin Related Armadillo Protein and β -catenin) that are expressed in both embryonic and post-natal tissues. Moreover, the domains of PS1 and PS2 that interact with these proteins have been identified. Applicants have also discovered that mutations in PS1 and PS2 affect the translocation of β -catenin into the nucleus of both native cells and cells transfected with a mutant PS gene. These discoveries provide the basis for materials and methods useful in the diagnosis and treatment of AD.

One object of the invention is directed to a method for identifying substances that alter the interaction of a presenilin protein with a presenilin-binding protein, comprising:

- (a) contacting at least the interacting domain of a presenilin protein to a presenilin-binding protein in the presence of a test substance, and
- (b) measuring the interaction of the presenilin protein and the presenilin-binding protein. Preferably, the interacting domain is contained in or contains the sequence of amino acid residues from about 260 to about 409 of a mutant PS1 protein, more preferably the sequence of amino residues from about 372 to about 399, in which the amino acid positions correspond to the wild-type human PS1 sequence defined by SEQ ID NO:1. When PS2 is used, the

sequence of amino acid residues from about 266 to about 390 are preferred, more preferably the sequence of amino residues from about 350 to about 380, in which the amino acid positions correspond to the wild-type human PS2 sequence defined by SEQ ID NO:2.

Substances identified that alter the interaction of a mutant presenilin protein with a normal presenilin-interacting protein, as well as the interaction of a normal presenilin protein with a mutant presenilin-interacting protein, are putative candidates for use in the diagnosis and treatment of AD.

Another object of the invention is to provide methods of identifying substances that modulate the nuclear translocation of an *armadillo* protein, comprising:

(a) providing a culture of cells that express the *armadillo* protein and a mutant presenilin protein, or a functional fragment thereof that binds said *armadillo* protein;

(b) contacting said culture with a test substance;

(c) inducing nuclear translocation of said *armadillo* protein in said cells; and

(d) measuring levels of nuclear *armadillo* protein as compared to a control as an indication of modulatory activity of said test substance. Alternatively, step (d) may comprise the step of measuring the effects of altered nuclear translocation such as: (i) alterations in transcription of downstream genes such as β APP, γ -secretase or by alteration in the activity of a transcription reporter assay such as the Tcf/Lef-luciferase assay; (ii) alterations in cellular responsiveness to signalling molecules (e.g., *Wnt*, EGF) which use armadillo proteins for intracellular signal transduction; or (iii) alterations in cell:cell adhesion (e.g., synapse formation) mediated by cytoplasmic armadillo proteins.

Armadillo proteins of the present invention include, but are not limited to, hNPRAP, p0071 and β -catenin. Cells may be native or recombinant (i.e., the mutant PS gene and/or the *armadillo* protein gene are/is transgenic to the cell).

It is another object of the invention to provide methods for screening for carriers of presenilin alleles associated with AD or related disorders, comprising:

(a) obtaining cells from an individual to be tested for Alzheimer's Disease or a related disorder;

(b) culturing said cells with a substance which induces nuclear translocation of an *armadillo* protein; and

(c) measuring levels of nuclear *armadillo* protein as compared to a control as an indication of the presence or absence of presenilin alleles associated with Alzheimer's Disease or a related disorder. Alternatively, step (c) may comprise measuring effects of altered nuclear translocation such as: i) alterations in transcription of downstream genes such as β APP, γ -secretase or by alteration in the activity of a transcription reporter assay such as the Tcf/Lef-luciferase assay; (ii) alterations in cellular responsiveness to signalling molecules (e.g., *Wnt*, EGF) which use armadillo proteins for intracellular signal transduction; or (iii) alteration in cell:cell adhesion (e.g., synapse formation) mediated by cytoplasmic armadillo proteins.

Inducement of nuclear translocation of the *armadillo* protein is preferably performed by activating the *Wnt/armadillo* signal transduction pathway of the cells. Most preferably, activation is with a lithium salt (e.g., lithium chloride) or with methods such as with recombinant *Wnt* proteins (or invertebrate homologues, e.g., Wingless proteins) applied exogenously to the medium or via transfection into the test cells.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows the amino acid sequences of GT24/hNPRAP and p0071 and the location of the 10 *armadillo* repeats.

DETAILED DESCRIPTION OF THE INVENTION

Applicants have identified the presenilin domain i.e., the interacting domain, that interacts with PS-interacting proteins, such as *armadillo* repeat proteins hNPRAP, p0071 and β -catenin, as including or contained in the sequence of amino acid residues from about 260 to about 409 of PS1 or corresponding residues from about 260 to about 390 in PS2. More preferably,

the interacting domain contains or is contained in amino acid residues from about 372 to about 399 of PS1 or corresponding residues from about 350 to about 380 in PS2. The amino acid sequences of wild-type human PS1 and PS2 are shown in SEQ ID NO:1 and SEQ ID NO:2, respectively.

Mutant PS1 and PS2 genes, and their corresponding amino acid sequences are described in Applicants' co-pending U.S. Application Serial No. 08/888,077, filed July 3, 1997, and incorporated herein by reference. Examples of PS1 mutants include I143T, M146L, L171P, F177S, A260V, C263R, P264L, P267S, E280A, E280G, A285V, L286V, Δ 291-319, L322V, G384A, L392V, C410Y and I439V. The mutations are listed with reference to their amino acid positions in SEQ ID NO:1. Examples of PS2 mutants include N141I, M239V and I420T. These mutations are listed with reference to their amino acid positions in SEQ ID NO:2. PS1 mutations A260V, C263R, P264L, P267S, E280A, E280G, A285V, L286V, Δ 291-319, G384A, L392V, and C410Y all occur in or near the interacting domain of PS1 described herein. However, the methods of the present invention are not limited to mutant presenilins wherein the interacting domain is mutated relative to the wild-type protein. For example, Applicants have observed that mutations in PS1 (e.g., M146L) which are not in the interacting domain (loop) also affect β -catenin translocation. These mutations probably disturb the presenilin *armadillo* interactions by altering the function of a high MW complex which contains the presenilin and *armadillo* proteins (plus others), as described in Yu *et al.*, 1998, *J.Biol.Chem.* 273:16460-16475; Levesque *et al.*, 1999, *J. Neurochem.*, in press; and Nishimura *et al.*, 1999, *Nature Medicine*, in press. Moreover, a comparison of the hPS1 and hPS2 sequences reveals that these pathogenic mutations are in regions of the PS1 protein which are conserved in the PS2 protein. Therefore, corresponding mutations in corresponding regions of PS2 may also be expected to be pathogenic and are useful in the methods described herein.

Proteins that interact with the presenilins, i.e., PS-interacting proteins, include the S5a subunit of the 26S proteasome (GenBank Accession No. 451007), Rab11 (GenBank Accession Nos. X5670 and X53143), retinoid X receptor B, also known as nuclear receptor co-regulator or MHC (GenBank

Accession Nos. M84820, X63522 and M87166) and GT24 (GenBank Accession No. U81004). These and other PS1 binding proteins such as *armadillo* proteins are described in Applicants' copending commonly assigned U.S. Application Serial No. 08/888,077, filed July 3, 1997, as well as U.S. Application Serial No. 08/592,541, filed January 26, 1996, the disclosures of which are incorporated herein by reference. The interaction between PS1 and β -catenin is reported by Zhou *et al.*, 1997, *Neuro. Report* (Fast Track) 8:1025-1029 and Yu *et al.*, 1998; Levesque *et al.*, 1999; and Nishimura *et al.*, 1999. Mutant forms as well as wild-type presenilin-interacting proteins may be used in the methods described herein. By presenilin-interacting proteins it is meant full-length proteins or fragments that contain the domain that interacts with the presenilin-interacting domain of a presenilin protein.

A first embodiment is directed to a method for identifying substances that alter the interaction of a presenilin protein with a presenilin-binding protein or which alter the functional consequences of the interaction. Candidate compounds which are shown to modulate these interactions may be produced in pharmaceutically useful quantities for use in the diagnosis and treatment of AD or related disorders. Candidate compounds include endogenous cellular components which interact with the presenilins *in vivo* and which, therefore, provide new targets for pharmaceutical and therapeutic interventions, as well as recombinant, synthetic and otherwise exogenous compounds which may have presenilin binding capacity and, therefore, may be candidates for pharmaceutical agents. Thus, in one procedure, cell lysates or tissue homogenates (e.g., human brain homogenates, lymphocyte lysates) may be screened for proteins or other compounds which bind to one of the normal or mutant presenilins. Alternatively, any of a variety of exogenous compounds, both naturally occurring and/or synthetic (e.g., libraries of small molecules or peptides), may be screened for presenilin binding capacity. In each of these embodiments, an assay is conducted to detect binding between a presenilin component containing at least the interacting domain of a presenilin protein described herein and some other moiety. Binding may be detected by indirect functional measures reflecting the functional consequences of the interaction

(e.g., changes in intracellular Ca^{2+} , Na^+ , K^+ , or GTP/GDP ratio, changes in apoptosis or microtubule associated protein phosphorylation, changes in $\text{A}\beta$ peptide production or changes in the expression of other downstream genes which can be monitored by differential display, 2D gel electrophoresis, differential hybridization, or SAGE methods) or by direct measures such as immunoprecipitation, the Biomolecular Interaction Assay (BIAcore) or alteration of protein gel electrophoresis. The preferred methods involve variations on the following techniques: (1) direct extraction by affinity chromatography; (2) co-isolation of presenilin components and bound proteins or other compounds by immunoprecipitation; (3) BIAcore analysis; and (4) the yeast two-hybrid systems. Other procedures include methods which detect abnormal processing of PS1, PS2, APP, or proteins reacting with PS1, PS2, or APP (e.g., abnormal phosphorylation, glycosylation, glycation amidation or proteolytic cleavage) alterations in presenilin transcription, translation, and post-translational modification; alterations in the intracellular and extracellular trafficking of presenilin gene products; or abnormal intracellular localization of the presenilins.

A second embodiment is directed to a method for identifying substances that modulate the nuclear translocation of *armadillo* proteins, preferably β -catenin, hNPRAP (GT24) and p0071. Nuclear translocation assays can advantageously be used as a biological monitor of the effects of PS1 and PS2 mutations that cause AD. This interaction can be modulated by compounds which strengthen or weaken the interaction between PS1 and PS2 and *armadillo* repeat proteins. This interaction assay method finds use in both the diagnosis and treatment of AD.

Generally, paired cell lines (e.g., vertebrate cells, such as the ones used in the Examples described herein or invertebrate cells, such as *D. melanogaster* cells) may be used in the method. One set of cells (control), expresses wild-type PS1 and wild-type *armadillo* protein (e.g., hNPRAP, p0071, β -catenin). The second set of cells expresses mutant PS1 and wild-type *armadillo* protein (test). By the terms PS1 and PS2, it is meant full-length or functional fragments thereof (e.g., residues 260-409 of PS1) that bind a normal or mutant *armadillo* protein. By the term *armadillo* protein, it is meant full-

length protein or functional fragments thereof (e.g., one or more *armadillo* repeats) that bind PS1 or PS2. For rapid *in vitro* assays, *armadillo* protein may be labelled with green-fluorescent protein (GFP) or blue fluorescence protein and transfected into the cells. PS1 or PS2 is preferably present in the form of a transgene, but cells in which PS1 and *armadillo* protein are endogenously expressed, such as patient fibroblasts or cultured neurons from transgenic mouse brain, may be used. All vertebrate cells express β -catenin, but not all *armadillo* proteins are expressed in all cell types. Thus, cells may be transformed with a transgene encoding the *armadillo* protein of choice. *Armadillo* proteins and their corresponding nucleotide and amino acid sequences are known in the art. The sequence of hNPRAP (GT24) is described in U.S. Application Serial No. 08/888,077, filed July 3, 1997, and is incorporated herein by reference.

The cells are then exposed to a candidate substance to be tested plus an environment or agent that induces nuclear translocation of the *armadillo* protein. In a preferred embodiment, nuclear translocation is achieved by culturing the cells in the presence of a lithium salt such as lithium chloride, exogenous recombinant *Wnt/Wingless* protein, NGF, EGF, A β , kinase inhibitors (e.g., Herbanycin A, Genstein or Lavendustin A), or phosphatase inhibitors such as Na⁺ Vanadate. These agents modulate the *Wnt/armadillo* signal transduction pathway in the cells. The last three named agents are less preferred than the first two agents (lithium and *Wnt/Wingless*) because they modulate phosphorylation of many proteins other than just β -catenin. In a most preferred embodiment, nuclear translocation is induced by contacting the culture with a lithium salt, preferably lithium chloride, or *Wnt/Wingless*.

Nuclear *armadillo* protein levels are preferably measured by direct visualization. Levels of nuclear *armadillo* protein in test cells versus controls cells are then compared to determine whether the test substance modulates the nuclear translocation of *armadillo* protein. In one preferred procedure, the cells are fixed and stained with anti- β -catenin antibodies (where β -catenin is the *armadillo* protein utilised). The amount of nuclear β -catenin is subsequently quantified by counting relative numbers of β -catenin (+) and β -catenin (-) nuclei, and/or by measuring the optic density of microscopic images

of nuclei. In another procedure, cells containing GFP-tagged- β -catenin are directly visualised for translocation in living cells under UV light. Nuclear β -catenin levels may be quantified as above. An advantage of this procedure is that it allows the same cell to be investigated using different conditions, for example using different quantities of the same or different test substances (drugs). In a further procedure, nuclei are isolated by known methods as described herein, and nuclear β -catenin levels are quantitatively measured by densitometry of signal intensity on Western blots probed with anti- β -catenin antibodies. In yet another procedure, nuclei from cells containing GFP-tagged β -catenin are isolated. Nuclear GFP- β -catenin is then quantified by direct measurement of GFP fluorescence signal intensity. In an alternative embodiment, the effects of altered nuclear translocation may be measured, e.g., measuring: (i) alterations in transcription of downstream genes such as β APP, γ -secretase or by alteration in the activity of a transcription reporter assay such as the Tcf/Lef-luciferase assay; (ii) alterations in cellular responsiveness to signalling molecules (e.g., *Wnt*, EGF) which use armadillo proteins for intracellular signal transduction; or (iii) alterations in cell:cell adhesion (e.g., synapse formation) mediated by cytoplasmic *armadillo* proteins. Such procedures are well known to those skilled in the art, as described in *Korinek et al.*, 1998, *Mol.Cell.Biol.* 18:1248-56; *Morin et al.*, 1997, *Science*, 275:1787-90; *Korinek et al.*, 1997, *Science*, 275:1784-87; and *Molenaar et al.*, 1996, *Cell*, 86:391-92. In each of these procedures, the control may be cells that express the normal presenilin and *armadillo* protein genes.

The interacting domain of the presenilins can be used, together with presenilin binding proteins, or fragments thereof that bind to the interacting domain of PS1 or PS2, to screen for substances that alter (e.g., facilitate, interfere, inhibit, prevent) binding of PS1 and/or PS2 to presenilin binding proteins or alter the functional consequences of binding (i.e., nuclear translocation of *armadillo* proteins, changes in β APP metabolism, transcription or translation, or changes in A β secretion). Such agents are candidates for use in the diagnosis or treatment of AD. Candidate substances may be selected from peptides, oligosaccharides, lipids, small molecules, compounds (drugs) or

derivatives of any of the foregoing, or other molecules. Substances to be used in the screening methods of the invention may be obtained e.g., from chemical or natural product libraries, including bacterial, fungal, plant and animal extracts. Substances can be tested in accordance with the invention for the ability to interfere with the binding of presenilin to a presenilin-binding protein. Such compounds may be found, for example, in natural product libraries, fermentation libraries (encompassing plants and microorganisms), combinatorial libraries, compound files, and synthetic compound libraries.

In yet another embodiment of the invention, a method is provided to screen for carriers of alleles associated with AD or related disorders, for diagnosis of victims of AD, and for screening and diagnosis of related presenilin and senile dementias, psychiatric diseases such as schizophrenia and depression, and neurological disease such as stroke and cerebral hemorrhage, associated with mutations in the PS1 or PS2 genes or presenilin binding proteins. Any eukaryotic cell may be used in the method. Control cells may be cells from a normal individual, i.e., absence of alleles associated with AD or related disorders.

In preferred embodiments, fibroblasts, leukocytes or neuronal cells are used. The *armadillo* protein assayed depends upon the type of cells obtained from the subject. Induction of nuclear translocation and visualization of the *armadillo* protein are conducted as described above. In an alternative embodiment, the effects of altered nuclear translocation may be measured in the cells obtained from the subject, e.g., measuring: (i) alterations in transcription of downstream genes such as β APP, γ -secretase or by alteration in the activity of a transcription reporter assay such as the Tcf/Lef-luciferase assay; (ii) alterations in cellular responsiveness to signalling molecules (e.g., *Wnt*, EGF) which use armadillo proteins for intracellular signal transduction; or (iii) alterations in cell:cell adhesion (e.g., synapse formation) mediated by cytoplasmic armadillo proteins. Such procedures are well known to those skilled in the art.

In general, modifications of the sequences encoding the polypeptides described herein may be readily accomplished by standard techniques such as chemical syntheses and site-directed mutagenesis. See Gillman *et al.*, 1979, *Gene* 8:81-97; Roberts *et al.*, 1987, *Nature* 328:731-734; and Innis (ed.), 1990, *PCR*

Protocols: A Guide to Methods and Applications, Academic Press, New York. Most modifications are evaluated by routine screening via an assay designed to select for the desired property.

These and other aspects of the invention are described in more detail by reference to the following examples.

EXAMPLE 1

To identify cDNAs encoding PS1-binding proteins, a yeast two hybrid library containing human adult brain cDNAs was screened using three overlapping "bait" cDNA sequences derived from the PS1₂₆₆₋₄₀₉ cytoplasmic loop. These bait sequences were: 1) a wild type PS1 TM6-TM7 loop (PS1₂₆₆₋₄₀₉); 2) a PS1 Exon 10 splice mutant, which construct corresponds to the FAD-linked Δ 290-319 mutation (PS1_{266-289/320-409}); and 3) a construct corresponding to the physiologic 18 kDa C-terminal cleavage fragment (PS1₂₉₀₋₄₆₇) which, in a six transmembrane (TM) model of PS1 topology, would be entirely cytoplasmic (Lehmann *et al.*, 1997, *J.Biol.Chem.* 272:12047-12051) but in an eight TM model would contain two additional TM domains (Doan *et al.*, 1996, *Neuron* 17:1023-1030).

The bait sequences were ligated into pAS2-1 (Clontech), were shown to be free of autonomous β -gal activation, and were independently co-transformed into Y190 *S. cerevisiae* together with a human brain cDNA library in pACT2 vector (Clontech). Transformants were selected for His⁺, β -gal⁺ activity, and the "trapped" candidate PS1 interacting cDNAs were isolated, sequenced, and analysed by BLASTN database searches. Negative control cDNAs included human Lamin C. Quantitative β -gal assays were performed according to the Matchmaker II protocol (Clontech).

Six of the 42 His⁺, β gal⁺ clones trapped by the wild type PS1₂₆₆₋₄₀₉ bait, one of ten clones trapped by the mutant PS1_{260-289/320-409} bait, and one of six clones trapped by the C-terminal PS1₂₉₀₋₄₆₇ bait represented overlapping clones derived from the same transcript, termed GT24. (GenBank Accession No. U81004.)

Nucleotides 2920-2997 of the GT24 cDNA overlap the anonymous microsatellite locus D5S478, therefore placing the GT24 gene on chromosome 5p15 near the Cri-du-Chat deletion locus, a syndrome associated with congenital malformation and gross mental retardation. This raises the distinct possibility that mutations or deletions in GT24 have a role in Cri-du-Chat syndrome. The GT24 sequence thus finds use in the diagnosis and therapy of Cri-du-Chat syndrome. On Northern blots, the GT24 gene is expressed as a range of transcripts of 3.9 to 5.0 kb in several regions of adult human brain, but is expressed at only very low levels in most non-neurologic tissues. The open reading frame (ORF) of the GT24 consensus cDNA encodes a protein of 1084 residues with a unique N-terminus, but with homology to proteins with *armadillo* (*arm*) repeat motifs at its C-terminus.

Searches of public nucleotide sequence databases also uncovered a murine orthologue of GT24, termed Neural Plakophilin Related Armadillo Protein (NPRAP), a protein of unknown function which contains approximately 147 additional amino acids at the N-terminus (*Paffenholz et al.*, 1997, *Differentiation* 61:293-304). It is unclear whether this difference reflects a true difference between the human and murine orthologues, or an artefact of cloning.

In addition to the GT24 clone (now known as human Neural Plakophilin Related Armadillo Protein (hNPRAP), one further His⁺, β gal⁺ yeast-two-hybrid clone (ps1ly2h-25) was found to encode another peptide with C-terminal *arm* repeats. Clone ps1ly2h-25 corresponds to a cDNA sequence deposited in GenBank as human protein p0071 (Accession Nos. U81005 and P18824). The ORF of ps1ly2h-25/p0071 has 47% overall amino acid sequence identity with hNPRAP, and 70% identity to the *arm* repeats at residues 390-906 of hNPRAP.

The amino acid sequence alignment of hNPRAP (U81004)(bottom line) and ps1ly2h-25/p0071 (U81005 and P18824)(top line)(solid vertical lines = identity; dotted vertical lines = similarity) is shown in Figure 1. Since the high GC content of the 5' end sequences (87%) resulted in the recovery only of truncated cDNA clones, residues 1-44 of hNPRAP were derived from genomic DNA sequences. There are 10 putative *armadillo* repeats

in hNPRAP which were identified using the *arm* consensus sequence (DKNDEKVVVTCAGTLHNLSVHNQNNKMIVRASGG) from PRODOM protein domain entry 138 (*Sonnhammer et al.*, 1994, *Protein Sci.* 3:482-492). These residues also show strong homology to *arm* repeats in other proteins such as P120cas (Z17804: 32-56% identity, $p=1.2 \times 10^{-133}$), human β -catenin (P35222:28-47% identity, $p=2.6 \times 10^{-4}$), and *D. melanogaster armadillo* (P18824: 26-43% identity, $p=1.9 \times 10^{-4}$).

Examples 2-5 illustrate both the specificity of the PS1:hNPRAP yeast two hybrid interaction and its occurrence under physiological conditions in mammalian cells.

EXAMPLE 2

Reciprocal immunoprecipitation (IP) experiments confirm that PS1 and hNPRAP specifically interact *in vitro* and that the hNPRAP:PS1 interaction requires the *arm* repeat of hNPRAP. Also shown is that hNPRAP interacts with PS2.

cDNAs encoding wild type PS1 (wtPS1) holoprotein, and various fragments of hNPRAP tagged at the C-terminus with a *myc*-tag (EQKLISEEDLN) and/or tagged at the N-terminus with a His-tag, green fluorescent protein (e.g. myc-hNPRAP₅₂₈₋₁₀₈₄), or Xpress-epitope tag (Invitrogen) were either transiently expressed (hNPRAP) or stably expressed (PS1) from the pcDNA3 vector (Invitrogen) or from the pEGFP-C1 vector (Clontech, Palo Alto, CA) in HEK293 cells. Endogenous β -catenin, α -catenin, γ -catenin, and calnexin were used.

Co-immunoprecipitation and glycerol velocity gradient fractionation were performed as previously described in *Yu et al.*, 1998, *J.Biol.Chem.* 273:16470-16475. Immunoprecipitations were performed on cell lysates 48 hours after transient transfections. Total proteins (2 mg/ml) were extracted from cultured cells or brain tissue using a lysis buffer (0.2% NP-40, 0.5% Triton X-100, 50 mM Tris-HCl [pH7.6], 150 mM NaCl, 2 mM EDTA, 2 mM PMSF, 2 mg/ml each of aprotinin, leupeptin, pepstatin). 1.0 mg proteins were incubated overnight with appropriate antibodies (anti-NPRAP [Y120], anti-PS1 antibody to the), C-terminus or to the TM6-TM7 PS1₂₆₀₋₄₀₉

cytoplasmic loop antibodies 520, 1143, 3027 (*Walter et al.*, 1996, *Molec. Medicine* 2:673-691), to c-myc [9E10.2], β -catenin, α -catenin, γ -catenin (Transduction Laboratories, Lexington, KY), calnexin (Stressgen, Vancouver, BC) or pre-immune serum as described in *Harlow et al.*, 1988, *Antibodies: A laboratory manual*. New York, Cold Spring Harbor Laboratory Press. Protein A Sepharose was subsequently added to the antibody-antigen complex and incubated for 2 hours at 4°C. The beads were washed four times with a washing buffer (0.2% NP-40, 50 mM Tris-HCl[pH7.6], 150 mM NaCl, 2 mM EDTA). IP products were resolved by SDS-PAGE and investigated for the co-immunoprecipitated partners with the corresponding antibody and detection with ECL (Amersham). 5% of the starting detergent lysate (50 mg) was loaded onto the cell extract lane. In experiments using cross-linking, cells were pretreated with 1 mM dithiobis-succinimidyl-propionate (DSP) for 20 min. on ice.

For glycerol velocity gradient fractionation, brain tissue (1.0 g) was homogenized in a total volume of 5.0 ml of 25 mM Hepes, pH 7.2 at 4°C with the protease inhibitors described above, and as described in *Yu et al.*, 1998. After spinning at 1000 x g for 15 minutes to remove cell debris and nuclei, the resulting supernatant was centrifuged at 100,000 x g for 60 minutes to collect cell membranes. The membranes were then washed for 45 minutes with a KCl buffer (1 M KCl, 25 mM Hepes, pH 7.2, and protease inhibitors) and centrifuged again at 100,000 x g for 60 min. Cell membranes were then lysed with 1.0 % Digitonin in 25 mM Hepes, pH 7.2, 100 mM KCl and protease inhibitors. 0.5 ml of membrane extracts (2 mg/ml) was applied to the top of a 11.5 ml 10-40% (w/v) linear glycerol gradient containing 25 mM Hepes, pH 7.2, 150 mM NaCl, 0.25% Digitonin. Gradients were centrifuged for 15 hours at 35,000 rpm and 4 °C using an SW41 rotor and collected by upward displacement into 1.0 ml fractions using an Isco model 640 density gradient fractionator.

Myc-tagged hNPRAP₅₂₈₋₁₀₈₄ was detected in whole lysates of *myc*-hNPRAP transfected control cells; in IP products from double-transfected HEK293 cells using the anti-PS1 N-terminal antibody 14.3 with prior DSP cross-linking; using anti-PS1₂₆₀₋₄₀₉ loop antibody with cross-linking or without prior cross-linking. No *myc*-hNPRAP was detected in cells transfected with

hNPRAP only and immunoprecipitated with anti-PS1 loop antibody, or in any cell precipitated with pre-immune (PI) serum or with beads but no antibody.

PS1 holoprotein was detected using anti-PS1 N-terminal antibody 14.3 in Western blots of whole lysates from a PS1-transfected control cells and in the anti-*myc* IP products of a double-transfected cell with no cross-linking.

No PS1 was detected in anti-*myc* IP products from cells transfected with *myc*-hNPRAP only, PS1 only, or precipitated with an irrelevant antibody.

PS1 holoprotein and C-terminal PS1 fragments were detected using anti-PS1 N-terminal and anti-loop antibodies (mixed) in Western blots of lysates from HEK293 cells stably expressing PS1 and transiently transfected with hNPRAP cDNA. PS1 holoprotein and C-terminal PS1 but not N-terminal PS1 were co-precipitated with *his*-tagged hNPRAP (residues 45-1085) on Ni-Agarose columns. An irrelevant *his*-tagged control protein (His-LacZ) did not co-precipitate any PS1. PS1 alone did not precipitate on the Ni-Agarose column.

Western blots using anti-*myc* antibody (9E10.2) detected *myc*-tagged hNPRAP in immunoprecipitates of HEK293 cells stably expressing PS1 and transiently transfected with *myc*-hNPRAP immunoprecipitation with anti-PS1 loop antibody 1143 and in immunoprecipitates of HEK293 cells stably expressing PS2 and transiently expressing *myc*-hNPRAP immunoprecipitation with anti-PS2 antibody 972. No *myc*-tagged hNPRAP was detected in IP products from PS2-only transfected cells or cells immunoprecipitated with pre-immune serum.

In cells expressing PS1 and *arm*⁺-hNPRAP, anti-*myc* antibodies (9E10.2) detected *myc*-tagged-*arm*⁺ hNPRAP peptide (GT24 residues 320-1085) in whole lysates and in anti-PS1 immunoprecipitates (anti-PS1 loop antibody 1143), but not in immunoprecipitates using pre-immune serum. The *myc*-tagged N-terminal *arm*⁻-hNPRAP peptide (residues 45-413) was detected in whole lysates of cells doubly transfected with PS1 and *arm*⁻-hNPRAP, but not in immunoprecipitates using either anti-PS1 antibodies or pre-immune serum.

This example shows: (1) PS1 and hNPRAP can be reciprocally co-immunoprecipitated from lysates of cells doubly transfected with full-length human PS1 and *myc*-tagged hNPRAP (*myc*-hNPRAP₅₂₈₋₁₀₈₄). However, co-immunoprecipitation did not occur in single transfected cells or from lysates of cells immunoprecipitated with pre-immune serum, with antibodies to unrelated proteins, or with Protein A Sepharose but no antibody; (2) a non-specific interaction between PS1 and hNPRAP can be excluded because neither protein co-precipitated with other irrelevant cellular proteins such as transfected His-LacZ or with other endoplasmic reticulum proteins such as endogenous calnexin (See Example 5); (3) the co-precipitation requires that the hNPRAP construct contain the C-terminal *arm* repeats (hNPRAP-*arm*⁺). Co-immunoprecipitation does not occur when the hNPRAP transcript encodes only the unique *arm*⁻ N-terminus of hNPRAP. Conversely, the *arm*-binding domain of PS1 must include residues Thr₃₂₀ to Ala₄₀₉ because: 1) residues 320-409 are the only residues common to all three PS1 yeast two hybrid "bait" constructs; and 2) hNPRAP co-precipitates PS1 holoprotein and PS1-CTF, but does not co-precipitate PS1-NTF. Within the PS1₃₂₀₋₄₀₉ domain, residues 372-399 contain a single *arm*-motif

(20% identity to *arm* consensus sequence) which is highly conserved in PS2 (91% identity) (Rogaev *et al.*, 1995, *Nature* 376:775-778), and in the invertebrate homologues (82% identity) (Levitan *et al.*, 1995, *Nature* 377:351-354; Boulianne *et al.*, 1997, *NeuroReport* 8:1025-1029).

EXAMPLE 3

To exclude the remote possibility that both the yeast-two-hybrid and the co-immunoprecipitation studies in double transfected cells were artifacts arising from over-expression, both co-immunoprecipitation and glycerol velocity gradient analyses were used to investigate the PS1:NPRAP interaction *in vivo* in the mammalian central nervous system (CNS). A rabbit polyclonal antibody (Y120) directed to residues 156-170 of human NPRAP (which are predicted to be unique to NPRAP and do not cross react with other *arm* proteins) was generated. The specificity of this antibody was confirmed by showing that it specifically recognized *myc*-tagged NPRAP in transiently transfected HEK293 cells, that the Y120 immunoreactive band could be abolished by pre-absorption of the antibody with the cognate peptide, and that the Y120 immunoreactive bands were also detected by an anti-*myc* monoclonal antibody. Both the anti-*myc* and the anti-hNPRAP antibodies detected an abundant protein of ~130 kDa (corresponding to full-length *myc*-tagged NPRAP), and an ~75 kDa species which likely represents a C-terminal proteolytic derivative. The hNPRAP antibody also detected a ~120 kDa species which is not detected by the *myc*-antibody, and which is likely an N-terminal proteolytic derivative lacking the *myc* epitope tag. However, both of these lower molecular weight species likely represent aberrantly processed derivatives peculiar to overexpression in HEK293 cells because, in contrast to the full length NPRAP species, they are not detectable in human brain homogenates. To confirm the PS1:NPRAP interaction, anti-hNPRAP antibody was used to investigate anti-PS1 immunoprecipitates from human post-mortem neocortex, and to show that NPRAP is strongly detectable in these anti-PS1 immunoprecipitates. Glycerol velocity gradient analysis of lysates of murine neocortex revealed that NPRAP co-fractionates with the high molecular weight PS1-NTF and PS1-CTF containing complexes (~250 kDa).

EXAMPLE 4

In situ hybridizations in post-natal brain tissue were performed on 18 μ m sections from approximately 4 month old murine brain (*Moser et al.*, 1991, *Neuron* 14:509-517). Digoxigenin-labelled antisense or sense strand cRNA probes were generated from the unique sequence at 788-1085 bp of hNPRAP cDNA (Boehinger Mannheim). Sections were hybridized with 100 μ L of either antisense or sense probe at a final concentration of 200 ng/ml in 50% formamide, 3 x SSC, 0.1% Ficoll, 0.1% polyvinylpyrrolidone, 1% BSA, 500 μ g/ml ssDNA, 500 μ g/ml tRNA, 10 mM DTT, 10% dextran sulphate at 45°C overnight in a humidified chamber, and then processed as described by *Takeichi et al.*, 1995, *Curr. Opin. Cell Biol.* 7:619-627. Day E8.5, E10.5, E11.5 and E13.5 embryos ("E" = embryonic post-conception) were fixed in 4% paraformaldehyde, 30-40% sucrose, embedded in OCT and sectioned at 12 μ m. Sections were processed as above except for the addition of digestion with 0.01% Proteinase K at 37°C for 20 min prior to the TEA acetic anhydride step.

In situ hybridization of digoxigenin-labelled anti-sense strand hNPRAP cRNA probes in 4 month post-natal mouse brain showed specific intense staining of neurons in hippocampus, dentate, scattered neocortical, cerebellar Purkinje and granule cells. There was prominent expression in CD1 mouse dorsal root ganglia and neural tube at day E13.5. Sense strand probes produced only minor background signals.

The *in situ* hybridization studies indicated that the transcriptional pattern of PS1 and NPRAP overlap in the brain of 4 month old mice and in murine embryos. In adult mouse brain both genes are expressed at high levels in dentate and hippocampal neurons, in scattered neocortical neurons, and in cerebellar Purkinje cells in adult mouse brain. (*Lee et al.*, 1996, *J. Neurosci.* 16:7513-7525; *Levesque et al.*, manuscript in prep; *Paffenholz et al.*, 1997, *Differentiation* 61:293-304). Similarly, there is overlap of the embryonic patterns of regional expression of PS1 and NPRAP. Both genes are prominently transcribed for instance in the neural tube and dorsal root ganglia at day E10.5. Confocal laser micrographs of disassociated MDCK cells transiently expressing PS1 (PS1 antibody 14.3, FITC conjugated secondary, green color) and His-

tagged-hNPRAP (using GT24 cDNA in pcDNA3.1 vector, Invitrogen) (anti-Express antibody, Rhodamine conjugated secondary, red color) showed colocalization of PS1 and hNPRAP. Experiments using *arm*⁻ constructs show diffuse cytoplasmic localization.

In MDCK cells forming intercellular contacts, Green Fluorescent Protein-tagged hNPRAP (pEGFP-C1 vector, Clontech, Palo Alto, CA) is predominantly localized near the cell membrane. Experiments using only *myc*-tagged hNPRAP showed similar results. These immunocytochemical studies in doubly-transfected CHO and MDCK cells revealed that transfected epitope tagged hNPRAP has a variable intracellular distribution. In disassociated cells, hNPRAP has a predominantly perinuclear cytoplasmic distribution contiguous with that of PS1. In contrast, in confluent cells with abundant cell:cell contacts, hNPRAP is predominantly located beneath the cell membrane close to inter-cellular contact zones.

The fact that only PS1 residues 320-409 are contained in all three PS1 yeast two hybrid "bait" constructs, the fact that the smallest hNPRAP "trapped" clone would be predicted to encode only the C-terminal *arm* repeat (residues 863-1084), and the results of the immunoprecipitation experiments cumulatively support that the PS1:hNPRAP interaction occurs between the C-terminal *arm* repeats in hNPRAP and residues Thr₃₂₀ to Ala₄₀₉ in PS1. Residues 372-399 of PS1 contain a single *arm*-motif (20% identity to *arm* consensus sequence) that is highly conserved not only in PS2 (91% identity) (Rogaev *et al.*, 1995, *Nature* 376:775-778), but also in the invertebrate homologues (82% identity) (Levitan *et al.*, 1995, *Nature* 377:351-354; Boulianne *et al.*, 1997, *NeuroReport* 8:1025-1029). As would be predicted, co-immunoprecipitation experiments in double transfected HEK293 cells reveal that PS2 also interacts with hNPRAP.

EXAMPLE 5

The validity of the PS1:hNPRAP interaction and the hypothesis that it arises from an interaction involving residues 372-399 of PS1 were confirmed by *in vitro* affinity chromatography experiments.

A His-tagged PS1 loop fragment corresponding to residues 266-409 was covalently linked to an Affi-Gel resin (BioRad) and then incubated with whole lysates of HEK293 cells stably expressing *myc*-tagged hNPRAP. The resulting complexes were washed repeatedly and the specifically interacting proteins were eluted in 1% SDS and examined by Western blotting using anti-*myc* antibodies. *In vitro* affinity chromatography suggests that the PS1:hNPRAP interaction involves the *arm*-repeat of hNPRAP and residues 372-399 of PS1. *myc*-tagged *arm*⁺-hNPRAP (GT24/*arm*⁺) can be detected on Western blots of eluates from the affinity column containing immobilized PS1 cytoplasmic loop residues 266-409. The presence of large quantities of *myc*-tagged hNPRAP in these eluates clearly demonstrates a high affinity for the PS1 loop. Binding is absent with resin alone, and greatly diminished by pre-incubation with recombinant PS1₃₇₂₋₃₉₉ peptide. *myc*-tagged *arm*⁻-hNPRAP (GT24/*arm*⁻) was not detected in the column eluate, but was present in the column flow through. The specificity of this interaction is supported by the following observations. First, *myc*-hNPRAP does not bind non-specifically to the blocked resin alone. Second, *myc*-tagged hNPRAP lacking the *arm* repeats (hNPRAP residues 43-413) does not bind to the immobilized PS1 loop, but appears in the in the column flow-through. Third, other *myc*-tagged cytoplasmic proteins (e.g. *myc*-tagged anti-secretory factor) do not bind to the immobilized PS1 loop. Finally, binding of hNPRAP to the immobilized PS1 loop domain can be competitively inhibited by pre-incubation of the hNPRAP-containing cell lysates with a synthetic peptide corresponding to the PS1 *arm*-like sequence at PS1 residues 372-399. The hNPRAP:PS1 interaction, however, was not affected by pre-incubation with a control peptide corresponding to the TM1-2 loop of PS1 (residues 100-133).

EXAMPLE 6

The results described in Examples 2-5 support the notion that there is a specific interaction between PS1 and hNPRAP. Since, however, the yeast-two-hybrid studies also detected an interaction between PS1 and a closely-related *arm* protein PS1ly28-25/p0071, a study was conducted to determine

whether PS1 might interact promiscuously with several members of the *arm*-repeat protein family.

Western blots of anti-PS1 immunoprecipitates from PS1 transfected HEK293 cells were examined for the presence of other *arm* proteins expressed endogenously in HEK293 cells. Endogenous β -catenin, but not endogenous α -catenin, γ -catenin, or calnexin were detected in Western blots of immunoprecipitation products from HEK293 cells stably transfected with PS1, using either antibodies to PS1 cytoplasmic loop or to the PS1 N-terminus. These studies reveal that the anti-PS1 immunoprecipitates contain endogenous β -catenin but not α -catenin or γ -catenin, and suggest that PS1 selectively interacts only with a subset of *armadillo* proteins. Endogenous β -catenin was also found to co-precipitate with transfected PS2 following immunoprecipitation of HEK293 cell lysates with anti-PS2 antibodies, but not with pre-immune serum.

EXAMPLE 7

In view of the effect of null mutations on developmental signalling pathways in *C. elegans* and mice (Leviton *et al.*, 1995, *Nature*, 377:351-354; Wong *et al.*, 1997, *Nature* 387:288-292; Shen *et al.*, 1997, *Cell* 89:629-639), the effect of mutations in PS1 and PS2 on the nuclear translocation of endogenous β -catenin following activation of the *Wnt/armadillo* signal transduction pathway by lithium induced inhibition of glycogen-synthetase-kinase-3 β (Stambolic *et al.*, 1996, *Curr. Biol.* 6:1664-1668) was examined to determine whether the PS:*arm* interactions had a functional role.

Nuclear β -catenin was quantitatively assessed either by immunocytochemistry in native fibroblasts or by Western blotting of nuclear fractions from transfected HEK293 cells. Native fibroblasts obtained by skin biopsy from normal subjects or subjects with PS1 or PS2 mutations were plated at low density. After approximately 65 hours the medium was replaced with media containing 20 mM lithium chloride for 3 hours. The cells were then fixed for 10 min. in 2% paraformaldehyde, incubated with 5% FBS for 30 min., stained with mouse monoclonal anti- β -catenin antibodies (1:500, Transduction Labs) at 4°C overnight, and counterstained with Hoechst 33342 dye (Molecular

Probes) to label nuclei. β -catenin positive and negative nuclei were then directly counted in approximately 400 cells from different fields.

HEK293 cell lines stably transfected with wild type PS1 (wt2 and sw/wt6), Leu392Val-mutant PS1 (VL25 and VL31), wild type PS2 (sw2-9), Asn141Ile mutant PS2 (sw2-VG1) (kindly provided by Dr. D. Selkoe), and Δ 290-319 mutant PS1 were grown in Dulbecco's modified Eagle's medium supplemented with 10% (v/v) fetal bovine serum, and were treated with lithium chloride at 5 mM final concentration for 3 hours (*Stambolic et al.*, 1996, *Curr. Biol.* 6:1664-1668). Nuclei were collected from lithium treated and control cells as previously described in *Dignam et al.*, 1983, *Nucl. Acid Res.* 11:1475-1489). Cells were washed once in ice-cold PBS, resuspended in hypotonic lysis buffer (10 mM Hepes (pH 7.9), 10 mM KCl, 0.1 mM EDTA, 0.5 mM dithiothreitol (DTT), 0.05% Nonidet P-40, 0.5 mM phenylmethylsulfonyl fluoride (PMSF), 10 μ g/ml aprotinin, 5 μ g/ml leupeptin), and incubated for 30 minutes on ice. The nuclei were pelleted by microcentrifugation at 3,500 rpm for 2 minutes at 4°C, and cytoplasmic fractions were collected from the supernatants. Cytoplasmic soluble β -catenin fractions were incubated with Concavalin A-Sepharose beads (Pharmacia Biotech) as previously described (*Miller et al.*, 1997, *J. Cell Biol.* 139:229-243). Nuclear fractions were extracted by resuspending the nuclei in a high-salt buffer (20 mM Hepes, 400 mM NaCl, 1 mM EDTA, 0.5 mM DTT, 0.5 mM PMSF, 10 μ g/ml aprotinin, 5 μ g/ml leupeptin) and then incubated with Concavalin A-Sepharose beads to remove contaminating cadherin-bound β -catenin. 5 μ g protein of each fraction was separated on 10% SDS-PAGE, and blots were probed with mouse monoclonal antibody against β -catenin (25 ng/ml, Transduction Lab.). Signals were detected by ECL (Amersham) and were quantified from the autoradiographs by the NIH Image software package.

To assess nuclear translocation of NF κ B, the same cells were incubated with medium alone or medium supplement with 50 ng/ml of Tumour Necrosis Factor- α (PeproTech Inc.) for 30 minutes, and then processed as above. Nuclear NF κ B was quantified on Western blots of nuclear preparations using rabbit polyclonal antibody to p65 subunit (Santa Cruz Biotechnology, Santa Cruz, CA).

Endogenous β -catenin in mock treated native human fibroblasts was diffused throughout the cell, or predominantly cytoplasmic. After lithium chloride treatment of wild type fibroblasts, β -catenin is strongly localized in nuclei. In heterozygous PS1 mutant fibroblasts (e.g., Ala260Val PS1, Leu286Val PS1 and Met146Leu) lithium induces very little nuclear translocation. Western blot analyses of nuclear preparations showed progressive accumulation of endogenous β -catenin at 0, 30, and 60 minutes after lithium chloride incubation of HEK293 cells transfected with wild type PS1 (wtPS1) or PS2 (wtPS2) but not mutant PS1 (L392V) or mutant PS2 (N141I).

Treatment of the same cells with $\text{TNF}\alpha$ induced increased translocation of $\text{NF}\kappa\text{B}$, but there were no differences between non-transfected, wild type or mutant PS1, or mutant PS2.

To investigate β -catenin ubiquitin:proteasome-mediated degradation pathways, HEK293 cells were incubated in medium containing 25 mM ALLN (N-acetyl-Leu-Leu-Norleucinal, Sigma) or ALLN plus 5 mM LiCl for 0, 1, 3, or 6 hours. Cells were harvested, lysates were prepared as previously described in *Yu et al.*, 1998, *J.Biol.Chem.* 273:16470-16475, and 10 mg of protein were subjected to SDS-PAGE and Western blotting followed by immunodetection using ECL and a mouse monoclonal anti- β -catenin antibody (Transduction Labs) as previously described in *Aberle et al.*, 1997, *EMBO J.* 16:3797-3804. Equivalent amounts of ubiquitinated and non-ubiquitinated β -catenin were detected in HEK293 cells expressing wild type or mutant PS1 following treatment with a proteasome inhibitor ALLN alone or ALLN with LiCl.

Cleared lysates of HEK293 cells stably expressing mutant or wild type PS1 were immunoprecipitated with a rabbit polyclonal antibody to the PS1₂₆₀₋₄₀₉ loop (1143), the immunoprecipitates were separated by SDS-PAGE, blotted and probed with monoclonal anti- β -catenin antibodies as described by *Yu et al.*, 1998. Equivalent amounts of endogenous β -catenin were co-immunoprecipitated from HEK293 cells with transfected wild type PS1 or mutant PS1. The transfected HEK293 cells contained equivalent amounts of immunoprecipitable PS1 (wt, Leu392Val or D290-319).

This example shows that mutations in PS1/PS2 modulate the translocation of β -catenin into the nucleus. There were no differences in basal levels of nuclear β -catenin between mutant or wild type native fibroblasts, or between untransfected HEK293 cells and HEK293 cells stably transfected with either wild type or mutant PS1 or PS2 cDNAs. However, upon stimulation of the *Wnt/armadillo* signal transduction pathway by incubation in medium containing 20 mM lithium chloride for three hours, normal fibroblasts showed pronounced translocation of β -catenin into the nucleus (nuclear β -catenin in 33/41 cells). In contrast, nuclear translocation of β -catenin was significantly reduced in fibroblasts from heterozygous carriers of the Met146Leu (87/349), His163Tyr (176/383), Ala260Val (88/337) and Leu286Val (69/370). Lithium-induced nuclear translocation of β -catenin was also significantly reduced in the PS2 Met239Val mutant fibroblasts (285/456). Nuclear translocation in the group of mutant PS1 fibroblasts was more affected than in mutant PS2 fibroblasts. This observation is in accordance with the reduced clinical penetrance and the later age of disease onset in families with PS2 mutations (mean ~ 65 years versus ~45 years for PS1 mutations) as described in *Bird et al.*, 1997, *Ann. Neurol.* 40:932-936. Similar results were obtained with the HEK293 cells. Thus, nuclear β -catenin levels substantially increased in HEK293 cells expressing either endogenous PS1/PS2 (6.8 fold), transfected wild type human PS1 (6.9 fold), or wild type PS2 (6.9 fold). In contrast, nuclear β -catenin levels increased only 2.1 fold in HEK293 cells with mutant PS1 (PS1 Leu392Val: 4.4 fold; PS1 Δ 290-319: 3.5 fold) and only 1.2 fold in cells expressing mutant PS2 (PS2 Asn141Ile: 1.8 fold). These differences in nuclear β -catenin are not associated with differences in total cellular β -catenin, and cannot be ascribed to differences in PS1 levels, because despite the fact that untransfected HEK293 cells express far lower levels of endogenous PS1, nuclear β -catenin levels were higher in lithium treated untransfected HEK293 cells than in the mutant PS1 transfected HEK293 cells. Finally, in contrast to the changes in nuclear translocation of β -catenin, nuclear translocation of NF κ B in response to Tumour Necrosis Factor- α was not affected by PS1 mutations. The latter observation argues that alterations in β -catenin mediated signal transduction

mechanisms associated with presenilin mutations does not arise from a non-specific abnormality in nuclear protein transport.

To confirm that the effect of PS1 missense mutations was a specific effect of pathogenic amino acid substitutions and did not occur with non-pathogenic substitutions, these experiments were repeated in fibroblasts from a heterozygous carrier of the PS1 Glu318Gly polymorphism (which is not associated with increased risk for AD or with abnormal bAPP processing - (Mattila *et al.*, 1998, *Ann. Neurol.* in press. Both basal nuclear b-catenin levels (29/489 nuclei) and Li⁺ induced nuclear translocation (343/451 nuclei) in the PS1 Glu318Gly fibroblasts were indistinguishable from normal control fibroblasts.

Based on these discoveries, Applicants believe that some of the PS1 mutations in the large cytoplasmic loop might directly disrupt the putative PS1:arm interaction domain at residues 372-399. However, quantitative liquid β -galactosidase assays indicate that there is not a large difference between the yeast-two-hybrid interaction of hNPRAP with wild type PS1₂₆₆₋₄₀₉ loop bait sequences compared to its interaction with the mutant Leu286Val PS1₂₆₆₋₄₀₉ bait sequences (β gal activities \pm SEM: Wild-type = 7.99 ± 0.33 ; L286V = 6.90 ± 0.50 units, $p = \text{n.s.}$). Furthermore, several of the mutations that were tested affect residues remote from the cytoplasmic loop. An alternate explanation revolves around a putative role for the presenilins and homologous proteins such as SPE4 in the docking and trafficking of a subset of cellular proteins such as the major sperm protein in the case of SPE4. In this regard, it may be relevant that another class of *armadillo* containing proteins, the importins (Gorlich, 1997, *Curr. Opin. Cell Biol.*, 9:412-419), are involved in the facilitation of translocation of proteins across the nuclear membrane (which together with the endoplasmic reticulum is a major intracellular site of presenilin protein expression (De Strooper *et al.*, 1997, *J. Biol. Chem* 272:3590-3598; Walter *et al.*, 1996, *Molec. Medicine* 2:673-691)). Presenilin mutations may cause a dominant gain of aberrant function by causing anomalous and/or misdirected trafficking of a limited number of interacting partners. This would be in agreement with results which suggest that presenilin mutations are associated with mistrafficking of β APP (Martin *et al.*, 1995, *NeuroReport* 7:217-220;

Scheuner et al., 1996, *Nature Med.*, 2:864-870; *Citron et al.*, 1997, *Nature Med.* 3:67-72; *Duff et al.*, 1996, *Nature* 383:710-713; *Borchelt et al.*, 1996, *Neuron*, 17:1005-1013).

Mutations in PS1 and PS2 may cause abnormalities in transcriptional activity in response to receptor mediated signals. Alternatively, by disturbing the intracellular compartmental distribution of *arm* proteins such as β -catenin, mutations in PS1 or PS2 may disturb their function at inter-cellular junctions. Interactions between catenins (such as β -catenin or APC) and cadherins (such as N-cadherin or cadherin-14) are thought to be important in the maintenance of CNS synapses (*Bhat et al.*, 1994, *J. Neurosci.* 14:3059-3071; *Takeichi*, 1995, *Curr. Opin. Cell Biol.* 7:619-627; *Uchida et al.*, 1996, *J. Cell Biol.* 135:767-779; *Shibata et al.*, 1997, *J. Biol. Chem.* 272:5236-5240). Synaptic dysmorphism and synaptic loss is a prominent part of the pathology of AD (*Masliah et al.*, 1993, *Brain Path* 3:77-85; *Jellinger*, 1996, *J. Neural Trans.* 47 (Suppl.):1-29).

Many modifications and variations of this invention can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. The specific embodiments described herein are offered by way of example only, and the invention is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled.

All patent and non-patent publications cited in this specification are indicative of the level of skill in the art to which this invention pertains. All these publications and patent applications are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

We claim:

1. A method for identifying substances that alter the interaction of a presenilin protein with a presenilin-binding protein, comprising:
 - (a) contacting at least the interacting domain of a presenilin protein to a presenilin-binding protein in the presence of a test substance, and
 - (b) measuring the interaction of the presenilin protein and the presenilin-binding protein.
2. The method of claim 1, wherein said interacting domain is mutated relative to the interacting domain of a normal PS1 protein.
3. The method of claim 1, wherein said interacting domain comprises amino acid residues from about 260 to about 409 of a mutant PS1 protein.
4. The method of claim 1, wherein wherein said interacting domain comprises amino acid residues from about 372 to about 399 of a mutant PS1 protein.
5. The method of claim 1, wherein said interacting domain comprises amino acid residues from about 266 to about 390 of a mutant PS2 protein.
6. The method of claim 1, wherein wherein said interacting domain comprises amino acid residues from about 350 to about 380 of a mutant PS2 protein.
7. A method for identifying substances that modulate the nuclear translocation of an armadillo protein, comprising:
 - (a) providing a culture of cells that express said armadillo protein and a mutant presenilin protein, or a functional fragment thereof that binds said armadillo protein;
 - (b) contacting said culture with a test substance;

(c) inducing nuclear translocation of said armadillo protein in said cells;
and

(d) measuring levels of nuclear armadillo protein as compared to a control as an indication of modulatory activity of said test substance.

8. The method of claim 7, wherein said armadillo protein is β -catenin.

9. The method of claim 7, wherein said armadillo protein is hNPRAP.

10. The method of claim 7, wherein said armadillo protein is p0071.

11. The method of claim 7, wherein (c) comprises culturing said cells in the presence of a lithium salt.

12. The method of claim 7, wherein said mutant presenilin protein comprises amino acid residues from about 260 to about 409 of a mutant PS1 protein.

13. The method of claim 7, wherein said mutant presenilin protein comprises amino acid residues from about 372 to about 399 of a mutant PS1 protein.

14. The method of claim 7, wherein said mutant presenilin protein comprises amino acid residues from about 266 to about 390 of a mutant PS2 protein.

15. The method of claim 7, wherein said mutant presenilin protein comprises amino acid residues from about 350 to about 380 of a mutant PS2 protein.

16. The method of claim 7, wherein said cells are selected from the group consisting of fibroblasts, leukocytes, neuronal cells, human embryonic kidney cells and D. melanogaster cells.

17. The method of claim 7, wherein said control comprises cells expressing a wild-type presenilin and said armadillo protein.
18. A method for screening individuals for presenilin alleles associated with Alzheimer's Disease or related disorders, comprising:
 - (a) obtaining cells from an individual to be tested for Alzheimer's Disease or a related disorder;
 - (b) inducing nuclear translocation of an armadillo protein in said cells;and
 - (c) measuring levels of said nuclear armadillo protein as compared to a control as an indication of the presence or absence of presenilin alleles associated with Alzheimer's Disease or a related disorder.
19. The method of claim 18, wherein (b) comprises culturing said cells in the presence of a lithium salt.
20. The method of claim 18, wherein said control comprises cells that express normal presenilin and said armadillo protein.
21. The method of claim 18, wherein said armadillo protein is β -catenin.
22. The method of claim 18, wherein said armadillo protein is hNPRAP.
23. The method of claim 18, wherein said armadillo protein is p0071.

1	MP..A.PEQASIVVEGQPTQRQEAASSTPGMEPETTATTILASVK.EQELQF.....QRLTRELEV.ERQIVASQLERCRLGAESPASIATSSSTERSF 88	p0071
1	MTENAGR...SLL...SO.....S...ALO.....LNS.KPEGSFQYPASVHSNQ..T..LALGE..TTPSQL.PAR.GTOAR..A.....TQGSF 61	gt24
89	PWRSTDVENTGVSKP..RV..SD.A..VQPNYLIRTEPEQTLYSPEQTSIHESEGS...LGNSR...SSTOMNSYSDSGYQEA...GSFHNSQNVSKAD 173	p0071
62	S.QOT....T..SRAGHLAGEPAPPPPPP...R.EP.....FAP...SL....GSAFHLPDAPFAAAAALY.YSXSTLP.APPRG...SP.LA.A. 130	gt24
174	NRQOHSFIGS.TNNHVVR.NSRA.EQOCTLVQPSVANRAMRRVSVSPRAQSPSYVISTOVSPSRGSLRTSLG..SGFGSPSVTDPRPLNPSAYSSTTLPAA 269	p0071
131	.PQ.G..GSPTK..LQGGG.APEGATY.....A.A.PRGSS.P.K.QSFS.....R..LAKS.Y.SFS....S.PIN.IVVSSAGL... 185	gt24
270	RAASPYSORPASPTAIRRIGSVTSRQTSNPNGTPTQYQTTARVGSPLTDAQTRVASPSQGVSSSPKRSGMT.AVQHLGSPSLQRTVHDHEQFGQO. 367	p0071
186	..IR....VTS.....P..PTV..QST..ISS.....SPIH.QL...SST..IG.TYAT...LSPT.KRLVHASEQYSKHS 235	gt24
368	QYDIY...ERNVPRPDSL.TGLRSSYASQHSQGLQDLRSV.SPDLHITPIYEGRTYY..SPVYR..SPNHGTVE.LQGSOTALYRTGV...S.GIGN.. 452	p0071
236	Q.ELYATATL..QRPGSLAAGSRASYSSQHGLGPBLR.ALQSPHHIDPIYEDRV.YQKPPM.RSLQSOG..DPLPPAHTGTYRTSTAPSSFCVDSVP 327	gt24
453	LQRTSSQRS.....TLTYQRNNYALNTTAT.YAEPYRPIQY..RVQECNYNRLQHAVPADDOT.TRSPSIDSIQKDPREFAWRDPELPEVIHMLEHQFPS 543	p0071
328	LQRTGSQHGPQNAAAATQFRASYA.AGPASNYADPYRQLQYCPVS.ESPYSKSGPALPP.EGTLARSPSIDSIQKDPREFCWRDPELPEVIQMLQHQFPS 424	gt24

FIGURE 1

FIGURE 1 CONT'D

SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANT: ST. GEORGE-HYSLOP, PETER H
ROMMENS, JOHANNA M
FRASER, PAUL E
- (ii) TITLE OF INVENTION: GENETIC SEQUENCES AND PROTEINS
RELATED TO ALZHEIMER'S DISEASE AND USES THEREFOR.
- (iii) NUMBER OF SEQUENCES: 2
- (iv) CORRESPONDENCE ADDRESS:
MENTLIK (A) ADDRESSEE: LERNER, DAVID, LITTENBERG, KRUMHOLZ &
(B) STREET: 600 SOUTH AVENUE WEST
(C) CITY: WESTFIELD
(D) STATE: NJ
(E) COUNTRY: USA
(F) ZIP: 07090-1497
- (v) COMPUTER READABLE FORM:
(A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: ASCII
- (vi) CURRENT APPLICATION DATA:
(A) APPLICATION NUMBER:
(B) FILING DATE:
(C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
(A) NAME: PALISI, THOMAS M
(B) REGISTRATION NUMBER: 36,629
(C) REFERENCE/DOCKET NUMBER: SCHERING 3.0-033
- (ix) TELECOMMUNICATION INFORMATION:
(A) TELEPHONE: (908) 654-5000
(B) TELEFAX: (908) 654-7866

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 467 amino acids
(B) TYPE: amino acid
(D) TOPOLOGY: linear
 - (ii) MOLECULE TYPE: protein
 - (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:
- ```

Met Thr Glu Leu Pro Ala Pro Leu Ser Tyr Phe Gln Asn Ala Gln Met
 1 5 10 15
Ser Glu Asp Asn His Leu Ser Asn Thr Val Arg Ser Gln Asn Asp Asn
 20 25 30
Arg Glu Arg Gln Glu His Asn Asp Arg Arg Ser Leu Gly His Pro Glu
 35 40 45
Pro Leu Ser Asn Gly Arg Pro Gln Gly Asn Ser Arg Gln Val Val Glu
 50 55 60
Gln Asp Glu Glu Glu Asp Glu Glu Leu Thr Leu Lys Tyr Gly Ala Lys
 65 70 75 80

```

His Val Ile Met Leu Phe Val Pro Val Thr Leu Cys Met Val Val Val  
                             85                                            90                                            95  
 Val Ala Thr Ile Lys Ser Val Ser Phe Tyr Thr Arg Lys Asp Gly Gln  
                             100                                            105                                            110  
 Leu Ile Tyr Thr Pro Phe Thr Glu Asp Thr Glu Thr Val Gly Gln Arg  
                             115                                            120                                            125  
 Ala Leu His Ser Ile Leu Asn Ala Ala Ile Met Ile Ser Val Ile Val  
                             130                                            135                                            140  
 Val Met Thr Ile Leu Leu Val Val Leu Tyr Lys Tyr Arg Cys Tyr Lys  
                             145                                            150                                            155                                            160  
 Val Ile His Ala Trp Leu Ile Ile Ser Ser Leu Leu Leu Leu Phe Phe  
                             165                                            170                                            175  
 Phe Ser Phe Ile Tyr Leu Gly Glu Val Phe Lys Thr Tyr Asn Val Ala  
                             180                                            185                                            190  
 Val Asp Tyr Ile Thr Val Ala Leu Leu Ile Trp Asn Phe Gly Val Val  
                             195                                            200                                            205  
 Gly Met Ile Ser Ile His Trp Lys Gly Pro Leu Arg Leu Gln Gln Ala  
                             210                                            215                                            220  
 Tyr Leu Ile Met Ile Ser Ala Leu Met Ala Leu Val Phe Ile Lys Tyr  
                             225                                            230                                            235                                            240  
 Leu Pro Glu Trp Thr Ala Trp Leu Ile Leu Ala Val Ile Ser Val Tyr  
                             245                                            250                                            255  
 Asp Leu Val Ala Val Leu Cys Pro Lys Gly Pro Leu Arg Met Leu Val  
                             260                                            265                                            270  
 Glu Thr Ala Gln Glu Arg Asn Glu Thr Leu Phe Pro Ala Leu Ile Tyr  
                             275                                            280                                            285  
 Ser Ser Thr Met Val Trp Leu Val Asn Met Ala Glu Gly Asp Pro Glu  
                             290                                            295                                            300  
 Ala Gln Arg Arg Val Ser Lys Asn Ser Lys Tyr Asn Ala Glu Ser Thr  
                             305                                            310                                            315                                            320  
 Glu Arg Glu Ser Gln Asp Thr Val Ala Glu Asn Asp Asp Gly Gly Phe  
                             325                                            330                                            335  
 Ser Glu Glu Trp Glu Ala Gln Arg Asp Ser His Leu Gly Pro His Arg  
                             340                                            345                                            350  
 Ser Thr Pro Glu Ser Arg Ala Ala Val Gln Glu Leu Ser Ser Ser Ile  
                             355                                            360                                            365  
 Leu Ala Gly Glu Asp Pro Glu Glu Arg Gly Val Lys Leu Gly Leu Gly  
                             370                                            375                                            380  
 Asp Phe Ile Phe Tyr Ser Val Leu Val Gly Lys Ala Ser Ala Thr Ala  
                             385                                            390                                            395                                            400  
 Ser Gly Asp Trp Asn Thr Thr Ile Ala Cys Phe Val Ala Ile Leu Ile  
                             405                                            410                                            415  
 Gly Leu Cys Leu Thr Leu Leu Leu Leu Ala Ile Phe Lys Lys Ala Leu  
                             420                                            425                                            430  
 Pro Ala Leu Pro Ile Ser Ile Thr Phe Gly Leu Val Phe Tyr Phe Ala  
                             435                                            440                                            445

Thr Asp Tyr Leu Val Gln Pro Phe Met Asp Gln Leu Ala Phe His Gln  
 450 455 460

Phe Tyr Ile  
 465

(2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 449 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Met Leu Thr Phe Met Ala Ser Asp Ser Glu Glu Glu Val Cys Asp Glu  
 1 5 10 15  
 Arg Thr Ser Leu Met Ser Ala Glu Ser Pro Thr Pro Arg Ser Cys Gln  
 20 25 30  
 Glu Gly Arg Gln Gly Pro Glu Asp Gly Glu Asn Thr Ala Gln Trp Arg  
 35 40 45  
 Ser Gln Glu Asn Glu Glu Asp Gly Glu Glu Asp Pro Asp Arg Tyr Val  
 50 55 60  
 Cys Ser Gly Val Pro Gly Arg Pro Pro Gly Leu Glu Glu Leu Thr  
 65 70 75 80  
 Leu Lys Tyr Gly Ala Lys His Val Ile Met Leu Phe Val Pro Val Thr  
 85 90 95  
 Leu Cys Met Ile Val Val Val Ala Thr Ile Lys Ser Val Arg Phe Tyr  
 100 105 110  
 Thr Glu Lys Asn Gly Gln Leu Ile Tyr Thr Pro Phe Thr Glu Asp Thr  
 115 120 125  
 Pro Ser Val Gly Gln Arg Leu Leu Asn Ser Val Leu Asn Thr Leu Ile  
 130 135 140  
 Met Ile Ser Val Ile Val Val Met Thr Ile Phe Leu Val Val Leu Tyr  
 145 150 155 160  
 Lys Tyr Arg Cys Tyr Lys Phe Ile His Gly Trp Leu Ile Met Ser Ser  
 165 170 175  
 Leu Met Leu Leu Phe Leu Phe Thr Tyr Ile Tyr Leu Gly Glu Val Leu  
 180 185 190  
 Lys Thr Tyr Asn Val Ala Met Asp Tyr Pro Thr Leu Leu Leu Thr Val  
 195 200 205  
 Trp Asn Phe Gly Ala Val Gly Met Val Cys Ile His Trp Lys Gly Pro  
 210 215 220  
 Leu Val Leu Gln Gln Ala Tyr Leu Ile Met Ile Ser Ala Leu Met Ala  
 225 230 235 240  
 Leu Val Phe Ile Lys Tyr Leu Pro Glu Trp Ser Ala Trp Val Ile Leu  
 245 250 255  
 Gly Ala Ile Ser Val Tyr Asp Leu Val Ala Val Leu Cys Pro Lys Gly  
 260 265 270  
 Pro Leu Arg Met Leu Val Glu Thr Ala Gln Glu Arg Asn Glu Pro Ile  
 275 280 285

|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Phe | Pro | Ala | Leu | Ile | Tyr | Ser | Ser | Ala | Met | Val | Trp | Thr | Val | Gly | Met |
| 290 |     |     |     |     |     | 295 |     |     |     |     | 300 |     |     |     |     |
| Ala | Lys | Leu | Asp | Pro | Ser | Ser | Gln | Gly | Ala | Leu | Gln | Leu | Pro | Tyr | Asp |
| 305 |     |     |     |     | 310 |     |     |     |     | 315 |     |     |     |     | 320 |
| Pro | Glu | Met | Glu | Glu | Asp | Ser | Tyr | Asp | Ser | Phe | Gly | Glu | Pro | Ser | Tyr |
|     |     |     |     | 325 |     |     |     |     | 330 |     |     |     |     | 335 |     |
| Pro | Glu | Val | Phe | Glu | Pro | Pro | Leu | Thr | Gly | Tyr | Pro | Gly | Glu | Glu | Leu |
|     |     |     | 340 |     |     |     |     | 345 |     |     |     |     | 350 |     |     |
| Glu | Glu | Glu | Glu | Glu | Arg | Gly | Val | Lys | Leu | Gly | Leu | Gly | Asp | Phe | Ile |
|     |     | 355 |     |     |     |     | 360 |     |     |     |     | 365 |     |     |     |
| Phe | Tyr | Ser | Val | Leu | Val | Gly | Lys | Ala | Ala | Ala | Thr | Gly | Ser | Gly | Asp |
| 370 |     |     |     |     |     | 375 |     |     |     |     | 380 |     |     |     |     |
| Trp | Asn | Thr | Thr | Leu | Ala | Cys | Phe | Val | Ala | Ile | Leu | Ile | Gly | Leu | Cys |
| 385 |     |     |     |     | 390 |     |     |     |     | 395 |     |     |     |     | 400 |
| Leu | Thr | Leu | Leu | Leu | Leu | Ala | Val | Phe | Lys | Lys | Ala | Leu | Pro | Ala | Leu |
|     |     |     |     | 405 |     |     |     |     | 410 |     |     |     |     | 415 |     |
| Pro | Ile | Ser | Ile | Thr | Phe | Gly | Leu | Ile | Phe | Tyr | Phe | Ser | Thr | Asp | Asn |
|     |     |     | 420 |     |     |     |     | 425 |     |     |     |     | 430 |     |     |
| Leu | Val | Arg | Pro | Phe | Met | Asp | Thr | Leu | Ala | Ser | His | Gln | Leu | Tyr | Ile |
|     |     | 435 |     |     |     |     | 440 |     |     |     |     | 445 |     |     |     |

# INTERNATIONAL SEARCH REPORT

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>IPC 6 G01N33/68 G01N33/566 G01N33/50                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | International Application No<br><b>PCT/CA 99/00018</b>                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br>IPC 6 G01N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Electronic data base consulted during the international search (name of data base and, where practical, search terms used)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Category *                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Relevant to claim No.                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | WO 97 27296 A (HSC RESEARCH AND DEVELOPMENT & UNIVERSITY OF TORONTO )<br>31 July 1997<br>cited in the application<br>see claims 57,72                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1-23                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | J. ZHOU ET AL.: "Presenilin 1 interaction in the brain with a novel member of the Armadillo family"<br>NEUROREPORT,<br>vol. 8, no. 8, 27 May 1997, pages 2085-2090, XP002067170<br>Dallas TX USA<br>see abstract; figure 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1-23                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <input type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| * Special categories of cited documents :                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;">           "A" document defining the general state of the art which is not considered to be of particular relevance<br/>           "E" earlier document but published on or after the international filing date<br/>           "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br/>           "O" document referring to an oral disclosure, use, exhibition or other means<br/>           "P" document published prior to the international filing date but later than the priority date claimed         </td> <td style="width: 50%; vertical-align: top;">           "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br/>           "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br/>           "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.<br/>           "&amp;" document member of the same patent family         </td> </tr> </table> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                             | "A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier document but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.<br>"&" document member of the same patent family |
| "A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier document but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.<br>"&" document member of the same patent family |                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Date of the actual completion of the international search<br><br><div style="text-align: center;">4 June 1999</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Date of mailing of the international search report<br><br><div style="text-align: center;">14/06/1999</div> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Name and mailing address of the ISA<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Authorized officer<br><br><div style="text-align: center;">Van Bohemen, C</div>                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA 99/00018

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| WO 9727296 A                              | 31-07-1997          | AU 1299297 A               | 20-08-1997          |
|                                           |                     | EP 0876483 A               | 11-11-1998          |
|                                           |                     | US 5840540 A               | 24-11-1998          |
|                                           |                     | AU 3251997 A               | 02-02-1998          |
|                                           |                     | WO 9801549 A               | 15-01-1998          |
|                                           |                     | EP 0914428 A               | 12-05-1999          |